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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of

HADA et al. Atty. Ref.: 2635-51

Serial No. 09/453,518 Group: 2751

Filed: December 3, 1999 Examiner: Olsen, K.

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For: GAS CONCENTRATION MEASURING APPARATUS DESIGNED TO MINIMIZE ERROR COMPONENT CONTAINED IN OUTPUT

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October 9, 2002

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

SUBMISSION OF CERTIFIED ENGLISH TRANSLATION OF PRIORITY DOCUMENT

As promised in applicant's September 9, 2002 submission (in the paragraph bridging the remarks at pages 12-13), a certified English translation of applicant's priority document is hereby submitted to demonstrate that applicant is entitled to priority rights as of December 4, 1998.

Respectfully submitted,

NIXON & VANDERHYE P.C.

By: Larry S. Nixon
Larry S. Nixon
Reg. No. 25,640

LSN:vc
1100 North Glebe Road, 8th Floor
Arlington, VA 22201-4714
Telephone: (703) 816-4000
Facsimile: (703) 816-4100

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In re PATENT APPLICATION OF
Inventors(s): Satoshi HADA et al.

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Filed: December 3, 1999

Title: GAS CONCENTRATION MEASURING APPARATUS DESIGNED TO MINIMIZE ERROR COMPONENT CONTAINED IN OUTPUT

VERIFIED TRANSLATION OF PRIORITY DOCUMENT

The undersigned, of the below address, hereby certifies that he/she well knows both the English and Japanese languages, and that the attached is an accurate translation into the English language of the Certified Copy, filed for this application under 35 U.S.C. Section 119 and/or 365, of:

Application No.	Country	Date Filed
10-345654	Japan	Dec. 4, 1998

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The undersigned declares further that all statements made herein of his/her own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 25th day of September, 2002.

Signature: Yoshiyuki Kaneko
Name: Yoshiyuki Kaneko

Address: 2-811, 9, Nishinohara 3-chome,
Inzai-shi, Chiba-ken, Japan

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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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Application Number: Patent Application No. 10-345654

Applicant(s): Denso Corporation
Nippon Soken, Inc.

October 8, 1999

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【 Filing Date 】	December 4, 1998
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【 Inventor 】	
【 Address or Abode 】	c/o Denso Corporation, 1-1, Showa-cho, Kariya-shi, Aichi-ken
【 Name 】	Satoshi HADA
【 Inventor 】	
【 Address or Abode 】	c/o Denso Corporation, 1-1, Showa-cho, Kariya-shi, Aichi-ken
【 Name 】	Eiichi KUROKAWA
【 Inventor 】	
【 Address or Abode 】	c/o Denso Corporation, 1-1, Showa-cho, Kariya-shi, Aichi-ken
【 Name 】	Tomoo KAWASE
【 Inventor 】	
【 Address or Abode 】	c/o Denso Corporation, 1-1, Showa-cho, Kariya-shi, Aichi-ken
【 Name 】	Toshiyuki SUZUKI
【 Inventor 】	
【 Address or Abode 】	c/o Denso Corporation, 1-1, Showa-cho, Kariya-shi, Aichi-ken
【 Name 】	Satoshi HASEDA

【 Applicant 】
【 Identification Number 】 000004260
【 Name or Designation 】 Denso Corporation
【 Applicant 】
【 Identification Number 】 000004695
【 Name or Designation 】 Nippon Soken, Inc.
【 Agent 】
【 Identification Number 】 100068755
【 Address or Abode 】 2-12-1, Oomiya-cho, Gifu-shi
【 Patent Attorney 】
【 Name or Designation 】 Hironobu ONDA
【 Telephone Number 】 058-265-1810
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[NAME OF DOCUMENT] SPECIFICATION

[TITLE OF THE INVENTION] GAS CONCENTRATION MEASURING DEVICE

[SCOPE OF THE INVENTION]

[CLAIM 1] A gas concentration measuring apparatus equipped with a gas concentration sensor measuring a concentration of a specified gas component of a gas to be measured and a signal processing circuit converting a result of measurement of said gas concentration sensor into a voltage signal and outputting the voltage signal, characterized in that a length of a signal line electrically connecting said gas concentration sensor and said signal processing circuit is specified according to a level of a detection signal of said sensor, and said signal line is shortened as a sensor signal is weaker.

[CLAIM 2] A gas concentration measuring apparatus as set forth in claim 1, wherein said signal processing circuit is installed in a connector for connection with an external device.

[CLAIM 3] A gas concentration measuring apparatus as set forth in claim 1 or 2, further comprising an impedance measuring circuit measuring an impedance of a sensor element portion of said gas concentration sensor, said impedance measuring circuit being integrated together with said signal processing circuit.

[CLAIM 4] A gas concentration measuring apparatus as set forth in

any one of claims 1 to 3, further comprising a heater which heats up a sensor element portion of said gas concentration sensor and a heater control circuit which controls a power supply to said heater, and wherein the heater control circuit is integrated together with said signal processing circuit.

[CLAIM 5] A gas concentration measuring apparatus as set forth in any one of claims 1 to 3, wherein the gas concentration measuring apparatus is mounted in a vehicle, and wherein the weaker the sensor signal in a condition of the mount, the shorter a distance between said gas concentration sensor and said signal processing circuit.

[CLAIM 6] A gas concentration measuring apparatus as set forth in any one of claims 1 to 5, wherein said gas concentration sensor includes a first cell responsive to application of a voltage to discharge excessive oxygen contained in the gas to be measured and to produce an electric current as a function of concentration of the discharged oxygen and a second cell responsive to application of a voltage to produce a second electric current as a function of concentration of the specified gas component contained in the gas from which the excessive oxygen is discharged by the first cell.

[CLAIM 7] A gas concentration measuring apparatus as set forth in any one of claims 1 to 6, wherein said signal processing circuit has a function of compensating for a unit-to-unit variation in characteristic of said gas concentration sensor.

[CLAIM 8] A gas concentration measuring apparatus as set forth in claim 7, wherein said signal processing circuit has a function of adjusting or correcting a variation in output characteristic of said gas concentration sensor in terms of the concentration of measured gas.

[CLAIM 9] A gas concentration measuring apparatus as set forth in claim 3, wherein said impedance measuring circuit has a function of adjusting or correcting a unit-to-unit variation in characteristic of said gas concentration sensor.

[CLAIM 10] A gas concentration measuring apparatus as set forth in claim 9, wherein said impedance measuring circuit has a function of adjusting or correcting a variation in temperature characteristic and a variation in output characteristic in terms of the impedance measured.

[CLAIM 11] A gas concentration measuring apparatus as set forth in claim 4, wherein said heater control circuit has a function of adjusting or correcting an error component arising from a wire resistance.

[CLAIM 12] A gas concentration measuring apparatus as set forth in claim 1, said signal processing circuit and other parts: the impedance measuring circuit measuring the impedance of the sensor element portion of said gas concentration sensor and a heater control circuit which controls a power supply to a heater of said gas concentration sensor, and wherein said signal processing circuit are bar

chip-mounted on a ceramic substrate or the like.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD OF THE INVENTION]

The present invention relates generally to a gas concentration measuring apparatus equipped with a gas concentration sensor for measuring the concentration of a specified gas component of a gas to be measured.

[0002]

[PRIOR ART]

Recently, NOx sensors designed to measure the concentration of nitrogen oxide (NOx) contained in exhaust emissions of automotive engines are proposed and being put into practical use. As one of such NOx sensors, a gas sensor which is capable of measuring the concentrations of NOx and O_2 simultaneously includes a pump cell for decomposing oxygen contained in exhaust gasses to measure the concentration of O_2 and a sensor cell for decomposing NOx in the oxygen-decomposed exhaust gasses to measure the concentration of NOx. In this case, application of a given voltage to each cell when the concentration of NOx or O_2 is measured causes a current to flow through each cell as a function of the concentrations of NOx or O_2. Its current signal it outputted from the sensor. A detected signal of each cell is converted into a voltage signal in a signal processing circuit and outputted to a control unit (engine control ECU).

[0003]

[PROBLEM TO BE SOLVED BY THE INVENTION]

However, in a case of the above described NOx sensor, a sensor cell current (i.e., the sensor signal according to the concentration of NOx) is very weak, so that it apt to interfere with electrical noises, resulting in an error in measuring the concentration of NOx. Specifically, when the concentration of NOx is within 0 to 2000ppm, a current output from the sensor is as little as 5 to 10 μA. Therefore, in the case where the gas concentration measuring apparatus is used in an engine control system of an automotive vehicle, signal outputs from other electrical devices are added to an output of the gas sensor as noises which will produce an error in measuring the concentration of NOx.

[0004]

The invention was made in view of the above problem. It is an object of the invention to provide a gas concentration measuring apparatus which minimizes the effect of noises and avoids an error in measuring the gas concentration.

[0005]

[MEANS FOR SOLVING THE PROBLEMS]

In order to achieve the above objects, the invention as recited in claim 1 features that in gas concentration measuring apparatus equipped with a gas concentration sensor measuring a concentration of a specified gas component of a gas to be measured and a signal processing circuit converting a result of measurement of said gas concentration sensor into a voltage signal and outputting the voltage signal, a length of a signal line electrically connecting said gas concentration sensor and said signal processing circuit is specified

according to a level of a detection signal of said sensor, and said signal line is shortened as a sensor signal is weaker.

[0006]

According to the above structure, it becomes possible to reduce the effect of noise even if the sensor signal is weak. As a result, the effect of the noise is decreased, thus avoiding an error in detection of the gas concentration to enable measurement of gas concentration with high accuracy. In this case, a maximum distance between the gas concentration sensor and the signal processing circuit can be specified, thereby also avoiding thermal effects near a sensor mount which is subjected to higher temperatures.

[0007]

As described in claim 6 specifically, in a case where said gas concentration sensor is implemented by a sensor including a first cell responsive to application of a voltage to discharge excessive oxygen contained in the gas to be measured and to produce an electric current as a function of concentration of the discharged oxygen and a second cell responsive to application of a voltage to produce a second electric current as a function of concentration of the specified gas component contained in the gas from which the excessive oxygen is discharged by the first cell, the current output of the second cell is weak, thus making it difficult to measure the concentration of the gas accurately subjected to noises. According to the structure, as defined in claim 1, the existing problem is solved, thereby providing a considerable effect.

[0008]

In the invention as recited in claim 2, said signal processing

circuit is installed in a connector for connection with an external device. In this case, the advantage that the structure can be simplified in addition to the above described effects.

[0009[

In the invention as recited in claim 3, it further comprises an impedance measuring circuit measuring an impedance of a sensor element portion of said gas concentration sensor. The impedance measuring circuit is integrated together with said signal processing circuit. In this case, it is possible to ensure the accuracy of detection of the impedance while eliminating the effect of the noise.

[0010]

In the invention as recited in claim 4, it further comprises a heater which heats up a sensor element portion of said gas concentration sensor and a heater control circuit which controls a power supply to said heater. The heater control circuit is integrated together with said signal processing circuit. In this case, it is possible to improve the controllability of the heater while eliminating the effect of the noise, thereby further resulting in improved accuracy of output of the sensor.

[0011]

In the invention as recited in claim 5, it is the gas concentration measuring apparatus mounted in a vehicle. The weaker the sensor signal in a condition of the mount, the shorter a distance between said gas concentration sensor and said signal processing circuit. In this case, it is possible to improve controllability of the heater while eliminating the effect of the noise, thereby further resulting in

improved accuracy of output of the sensor.

[0012]

On the other hand, an element of the gas concentration sensor is made of ceramic which is subjected to a great unit-to-unit variation in characteristic in production, so that a production yield in production is low. The variation in characteristic as referred to herein is, for example, a variation in output characteristic of the sensor signal in terms of the concentration of the gas to be measured, a variation in dc characteristic of the sensor, or a variation in ac characteristic. Since the resistance value of the heater is lower in an effort to activate the gas concentration sensor early, a difference in resistance of leads between vehicles will result in a variation in control of the heater, which leads to a problem of abnormality of the heater control. Specifically, reduction in heating ability of the heater and errors in detecting power of the heater results in a delay in acting the element portion and excessive rise in temperature.

[0013]

In order to avoid these problems, claims 7 to 11, as described above, are proposed. Specifically, in the invention as recited in claims 7 to 10, said signal processing circuit and said impedance measuring circuit have a function of compensating for a unit-to-unit variation in characteristic of said gas concentration sensor. It means that a variation in output characteristic of said gas concentration sensor in terms of the concentration of measured gas, a variation in temperature characteristic in terms of the detected impedance, or a variation in output characteristic of the sensor is adjusted or corrected.

In the invention as recited in claim 11, said heater control circuit has a function of adjusting or correcting an error component arising from a wire resistance.

[0014]

In the invention as recited in claims 7 to 11, it is advisable that, for example, adjustment of a gain or an offset in each circuit be achieved. Specifically, adjustment parts may be installed or a thin film resistor is installed through thin film trimming. As one example, output characteristics of each sensor in terms of the concentration of a gas detected may trims, for example, a current measuring shunt resistance or adjusting a gain offset of a current measuring amplifier circuit. The adjustment or correction function serves to eliminate a unit-to-unit difference of the gas concentration sensor, thus permitting an actual output of the sensor to be brought into agreement with an optimum characteristic. This also results in stability of heater controllability and alleviates the problems of a delay in activating the element portion and an excessive rise in temperature. This results in greatly improved production yield of the gas concentration sensor and the gas concentration apparatus.

[0015]

In the invention as recited in claim 12, said signal processing circuit and other parts: the impedance measuring circuit measuring the impedance of the sensor element portion of said gas concentration sensor and a heater control circuit which controls a power supply to a heater of said gas concentration sensor. The signal processing circuit are bar chip-mounted on a ceramic substrate or the like. This results

in reduction in size and improved thermal resistance and vibrational resistance and accuracy of output of the sensor.

[0016]

[EMBODIED FORM OF THE INVENTION]

Hereinbelow, one embodied form of a gas concentration measuring apparatus as used with a control system will be explained with reference to drawings. In the engine control system in this embodied form, a gas concentration sensor that is the so-called composite gas senor capable of measuring the concentrations of oxygen and NOx in exhaust emissions simultaneously is installed in an engine exhaust pipe. Air/fuel ratio feedback (F/B) control and diagnostic processing of exhaust gas purifying catalyst are performed.

[0017]

Fig. 1 is a structural view which shows the summary of the engine control system in this embodied form. In Fig. 1, the engine 10 is constructed as a multi-cylinder four cycle internal combustion engine. A fuel injector 12 is installed in an intake pipe 11 to supply the fuel to each cylinder of the engine 10. The gas concentration sensor 100 is installed in an exhaust pipe 13 and outputs detection signals indicative of the concentration of O_2 and NOx.

[0018]

Here, the structure of the gas concentration sensor 100 with a two-cell structure will be described using Fig. 3. The gas concentration sensor 100 is made of a lamination of the pump cell 110 (first cell), the sensor cell 120 (second cell), a porous diffused layer 101, an air duct 102, and a heater 103. The gas concentration sensor 100

is installed at the right side thereof, as viewed in the drawing, on the exhaust pipe 13 of the engine so as to expose upper, lower, and left surfaces to exhaust gasses.

[0019]

In more detail, the pump cell 110 is disposed between the porous diffused layer 101 and the exhaust gas space. A first pump cell electrode 111 is mounted on an exhaust gas side (upper side of the drawing) of the pump cell 110. A second pump cell electrode 112 is mounted on the side (lower side of the drawing) of the porous diffused layer 101. The sensor cell 120 is interposed between the porous diffused layer 101 and the air duct 102. A first sensor cell electrode 121 is disposed on the porous diffused layer 101 side (upper side of the drawing) of the sensor cell 120. A second sensor cell electrode 122 is disposed on the air duct 102 side (lower side of the drawing) of the sensor cell 120. The exhaust gasses enters the porous diffused layer 101 from the left side thereof, as viewed in the drawing, and flow in the right direction.

[0020]

The pump cell 110 and the sensor cell 120 are each formed with a solid electrolyte lamination which is made of an oxygen ion conductive oxide sintered member made from ZrO_2, HfO_2, ThO_2, and Bi_2O_3 in which CaO, MgO, Y_2O_3, and Yb_2O_3 are solved as fixing agents. The porous diffused layer 101 is made of a heat-resisting inorganic matter such as alumina, magnesia, silica, spinel, and mullite.

[0021]

The first pump cell electrode 111 on the exhaust gas side of the

pump cell 110 and the first and second sensor cell electrodes 121 and 122 of the sensor cell 120 are made of a noble metal with a high catalytic activity such as platinum (Pt), while the second pump electrode 112 on the porous diffused layer 101 of the pump cell 110 is made of a noble metal such as Au-Pt which is inactive with respect to NOx, that is, hardly decomposes NOx.

[0022]

The heater 103 is embedded in the insulating layer 104. The insulating layer 104 defines the air duct 102 between itself and the sensor cell 120. The air duct 102 serves as a reference gas chamber into which the air is introduced from the outside. The air in the reference gas chamber is used as a reference gas in measuring the concentration of O_2. The insulating layer 104 is made of alumina. The heater 103 is made of platinum and cermet such as alumina and supplied with power from the outside to produce the heat for activating the whole of the gas concentration sensor 100 (including the electrodes).

[0023]

An operation of the gas concentration sensor 100 of the above structure will be explained using Fig. 4.

As shown in Fig. 4(a), exhaust gas components enter the porous diffused layer 101 from the left side of the drawing. When the exhaust gas component passes the pump cell 110, application of voltage to the pump cell 110 causes decomposition reaction. The exhaust gas components contain , when exhaust gasses containing oxygen (O_2), oxide nitride (NOx), carbon nitrogen (CO_2), and water (H_2O).

[0024]

Since the second pump cell electrode 112 of the pump cell 110 is, as described above, made of a NOx inactive electrode (i.e., an electrode which hardly decomposes NOx), only oxygen (O_2) contained in the exhaust gasses is decomposed by the pump cell 110, as shown in Fig. 4(b), which are, in turn, discharged to the exhaust gasses from the first pump cell electrode 111. At this time, a current flowing through a pump cell 110 is detected as the concentration of oxygen contained in the exhaust gasses.

[0025]

The oxygen (O_2) in the exhaust gasses is usually not decomposed by the pump cell 110 completely, so that the part thereof passes and flows near the sensor cell. The application of voltage to the sensor cell 120, as shown in Fig. 4(c), causes the first sensor cell electrode 121 to decompose the residual oxygen (O_2) and NOx. Specifically, the residual oxygen and NOx are decomposed by the first sensor cell electrode 121 of the sensor cell 120 and discharged through the sensor cell 120 from the second sensor cell electrode 122 to the air in the air duct 102. At this time, the current flowing through the sensor cell 120 is detected as the concentration of NOx contained in the exhaust gasses.

[0026]

Next, characteristics of the pump cell 110 for detecting the oxygen concentration and the sensor cell 120 for detecting the NOx concentration will be explained using Figs. 5 and 6. First, the pump cell characteristics will be explained using Fig. 5.

[0027]

As shown in a V-I characteristic view, the pump cell has a limiting current characteristic in terms of the oxygen concentration. In the same drawing, a limiting current detecting range is defined by a straight portion parallel to a V-axis, and its area is shifted to the positive voltage side as the concentration of oxygen is increased.

[0028]

Here, if the applied voltage is kept constant when the concentration of O_2 is changing, it is difficult to measure the concentration of O_2 accurately using the above described limiting current detecting range (i.e., the straight portion parallel to the V-axis). This also means that a large quantity of O_2 is not discharged from the pump cell 110, so that oxygen remaining in the sensor cell 120 is increased, thereby causing an error of the current for detecting the NOx concentration to be increased. Therefore, application of the voltage equivalent to the angle of a dc current resistance component of the pump cell (i.e., a portion of an inclination of an increase with an increase in applied voltage), that is, the voltage, as shown by an applied voltage line LX1 in Fig 5 is controlled, thereby enabling detection of a desired sensor current (limiting current) at all times regardless of the concentration of oxygen in the exhaust gasses.

[0029]

Next, the sensor cell characteristic will be explained using Fig. 6. As shown in V-I characteristic view of Fig. 6, the sensor cell has a limiting current characteristic in terms of the NOx concentration. In the same drawing, in a range A1, a current (offset current) arising from

an offset produced by the residual oxygen flowing through the porous diffused layer 101 to the sensor cell 120 flows. In a range A2, a NOx decomposition current flows (in the drawing, a case of 1000ppm is shown). In a range where a current exceeding A1 + A2, that is, the current on the right end of the drawing increases (when the NOx concentration is 1000ppm, an A3 portion), the decomposition current of H_2O flows. At this time, the limiting current corresponding to the NOx concentration in the exhaust gasses is detected as A1 + A2 current value. The limiting current detecting range specifying the NOx decomposition current is formed by a straight portion parallel to the V-axis, and its area is shifted to the positive voltage side slightly as the NOx concentration is increased. When the NOx concentration is detected, applied voltage is controlled along the applied voltage line LX2, thereby enabling detection of a desired sensor current (limiting current) regardless of the NOx concentration in the exhaust gasses.

[0030]

On the other hand, in Fig. 1, the electronic control unit 20 (will referred to as ECU below) picks in engine running information (engine speed, inlet air pressure, water temperature, and throttle opening) from the gas concentration sensor 100 and other sensor groups (not shown) and controls the quantity of fuel supplied by the fuel injector 12 and the ignition timing through an ignition system 15 suitably based on results of detection of these sensors. The oxygen concentration signal (A/F signal) and NOx concentration signal transmitted from the sensor control circuit M10 are inputted to the ECU 20.

[0031]

The sensor control circuit M10 picks up the current signal detected as a function of the oxygen concentration of the exhaust gasses and the current signal detected as a function of the NOx concentration from the gas concentration sensor 100, determines an oxygen concentration output and a NOx concentration output based on the current signals and outputs them to the ECU 20. The sensor control circuit M10 also picks up element temperature information (element resistance information) indicating the status of activation of the gas concentration sensor 100 and outputs it to the ECU 20.

[0032]

The heater control circuit M20 controls the power supply to the heater 103 based on real-time element temperature information (i.e., the element resistance information) for maintaining the gas concentration sensor 100 activated. The detailed structures of the sensor control circuit M10 and the heater control circuit M20 will be described later.

[0033]

Here, a chain-dot line frame, as denoted at reference numeral 300, is a connector for connection with an external device. The sensor control circuit M10 and the heater control circuit M20 are illustrated as being built in the connector 300. The gas concentration sensor 100 and the sensor control circuit M10 in the connector 300 are electrically joined to each other through a signal line H1. The heater 103 and the heater control circuit M20 in the connector 300 are electrically joined to each other through a signal line H2.

[0034]

Fig. 11 is a perspective view which shows the exterior of the gas concentration sensor 100 and the connector 300. In Fig. 11, the gas concentration sensor 100 has said pump cell 110, the sensor cell 120, and the element portion 150 in which the heater 130 is provided integrally. A cover 160 is disposed around the element portion 150 which has many small holes in its periphery. The connector 300 includes a casing 310 and a connecting portion 320. Within the casing 310, an electrical circuit constituting said sensor control circuit M10 and the heater control circuit M20 is disposed.

[0035]

Additionally, as shown in a block diagram of Fig. 2, the sensor control circuit M10 includes an oxygen concentration determining circuit M11, a NOx concentration determining circuit M12, and an element impedance measuring circuit M13. In this embodiment, the oxygen concentration measuring circuit M11 and the NOx concentration measuring circuit M12 correspond to a signal processing circuit as recited in a claim.

[0036]

The oxygen concentration determining circuit M11 is connected to the pump cell 110 of the gas concentration sensor 100 to pick in the current value flowing through the pump cell 110 as a function of the concentration of oxygen in the exhaust gasses and converts it into a voltage signal which is, in turn, outputted to the external device. The oxygen concentration determining circuit M11 is also responsive to the real-time pump cell current to variably adjust the pump cell-applied voltage. The NOx concentration determining circuit M12 is connected

to the sensor cell of the gas concentration sensor 100 to pick in the current value flowing through the sensor cell 120 as a function of the concentration of NOx in the exhaust gasses and converts it into a voltage signal which is, in turn, outputted to the external device. The NOx concentration determining circuit M12 is also responsive to the real-time sensor cell current to variably adjust the sensor cell-applied voltage.

[0037]

The sensor element impedance measuring circuit M13 measures the impedance of the sensor cell 120 (or the pump cell 110) in a sweep method and outputs information about the measured impedance to the heater control circuit M20.

[0038]

The heater control circuit 520 is responsive to the element impedance information outputted from the sensor cell impedance measuring circuit M13 to control the power supply to the heater 103. The contents of heater control which may be embodied in this case are disclosed in detail, for example, in Japanese Patent Application No. 10-275521 and Japanese Patent First Publication No. 8-278279.

[0039]

More detailed structures of Figs. 1 and 2 are shown in Fig. 7. In the device of Fig. 7, the control circuit 200 is made of a microcomputer 200 consisting of a CPU, A/D converters, and D/A converters. To the A/D converters A/D0 to A/D3, voltages appearing at terminals *Vc, Ve, Vd,* and *Vb* are inputted. From the D/A converters D/A1 and D/A0, a pump command voltage *Vb* and the

sensor command voltage *Vc* are outputted. From the D/A converters D/A2 and D/A3, an O_2 concentration output and a NOx concentration output are outputted.

[0040]

The command voltage *Vb* outputted from the D/A1 of the control circuit 200 is inputted to an non-inverting input of the amplifier circuit 211. An output of the amplifier circuit 211 is connected to one end of the resistor 212 used in measuring the pump cell current *Ip* flowing through the pump cell 110 as a function of the concentration of O_2. The other end of the resistor 212 is connected to the first pump cell electrode 111 of the gas concentration sensor 100 and an inverting input of the amplifier circuit 211, thereby controlling the voltage appearing at the first pump cell electrode 111 so as to be kept at the same potential as the pump cell control voltage *Vb*. The resistor 212 also connects at both ends to the A/D converters A/D2 and A/D3.

[0041]

Therefore, application of the command voltage *Vb* to the pump cell 110 from the sensor control circuit M10 will cause the pump cell current *Ip* to flow through the resistor 212. The pump cell current *Ip* is given by the following equation in terms of a difference between the terminal voltages Vd and Vd of the current detecting resistor 212 and the resistance value R1 of the current detecting resistor 212:

$$Ip = (Vd - Vb) / R1$$

The control circuit 200, the amplifier circuit 211 ,and the current detecting resistor 212 constitute the oxygen concentration measuring circuit M11 of Fig. 2.

[0042]

The command voltage *Vc* outputted from the D/A converter D/A0 of the control circuit 200 is inputted to an non-inverting input of the amplifier circuit 221 through a LPF (low-pass filter) 230. The low-pass filter 230 may be a primary filter consisting of a capacitor. An output of the amplifier circuit 221 is connected to one end of the resistor 222 used in measuring the sensor cell current *Is* flowing as a function of the concentration of NOx. The other end of the resistor 222 is connected to the second sensor cell electrode 122 of the gas concentration sensor 100 and an inverting input of the amplifier circuit 221, thereby controlling the voltage appearing at the second sensor cell electrode 122 to be kept at the same potential as the sensor cell control voltage *Vc*. The resistor 222 connects at both ends thereof to the A/D converters A/D0 and A/D1 of the microcomputer 200.

[0043]

Therefore, application of the command voltage *Vc* to the sensor cell 120 from the sensor control circuit 510 will cause the sensor cell current *Is* to flow through the resistor 222. The sensor cell current *Is* is given by the following equation in terms of a difference between the terminal voltages Ve and Vc of the current detecting resistor 222 and the resistance value R2 of the current detecting resistor 222:

$$Is = (Ve - Vc) / R2$$

The microcomputer 200, the amplifier 221, and the resistor 222 constitute the NOx concentration determining circuit M12.

[0044]

The microcomputer 200 measures an a.c. impedance of the sensor cell 120 using the sweep method. Specifically, the measurement of the impedance is achieved by changing the sensor cell-applied voltage from the D/A converter D/A0 instantaneously to apply an ac voltage to the sensor cell 120 which is blurred in the form of a sine wave through the low-pass filter 230. The frequency of the ac voltage is preferably higher than 10KHz. The time constant of the low-pass filter 230 is in the order of 5 μ s. The microcomputer 200 monitors changes in voltage *Ve* and *Vc* appearing at the terminals *Ve* and *Vc* through the A/D converters A/D1 and A/D0 to determine a change in voltage difference across the resistor 222 and a change in sensor current and calculates the a.c. impedance of the sensor cell 120 based on the changes in voltage difference and sensor current. The microcomputer 200 outputs a signal indicative of the a.c. impedance of the sensor call 120 to the external through a D/A converter or a serial communication port. The microcomputer 200, the amplifier 221, and the resistor 222 constitute the sensor element impedance measuring circuit M13.

[0045]

The microcomputer 200 outputs a control signal having a given duty factor through an I/O port to operate a MOSFET driver 300. The MOSFET 310 regulates the power supplied from a power source 320

(e.g., a battery) to the heater 103 under the PWM control. The microcomputer 200, the MOSFET driver 300, and the MOSFET 310 constitute the heater control circuit M20.

[0046]

Next, applied voltage control executed by the CPU in the control circuit 200 will be explained according to a flowchart as shown in Fig. 8. Processing of Fig. 8 is an applied voltage control subroutine performed in the course of a main routine not shown.

[0047]

In Fig. 8, first in steps 101 and 102, the terminal voltages *Vd* and *Vb* of the current detecting resistor 212 of Fig. 7 are read out of the A/D converters A/D2 and A/D3. Next, in steps 103 and 104, the terminal voltages *Ve* and *Vc* of the terminals *Ve* and *Vc* are read out of the A/D converters A/D3 and A/D0, respectively.

[0048]

In step 105, the pump cell current *Ip* is determined. In a subsequent step 106, a target input voltage is determined which corresponds to the pump cell current *Ip* on the voltage line LX1 shown in Fig. 5 (map calculation is performed). In step 107, the target input voltage determined in step 106 is outputted as the command voltage *Vb* through the D/A converter D/A1. Next, in step 108, the sensor cell current *Is* is determined. In a following step 109, a target input voltage to be applied to the sensor cell 120 is determined which corresponds to the sensor cell current *Is* on the voltage line LX2 shown in Fig. 6 (map calculation is performed). In step 110, the target input voltage determined in step 109 is outputted as the command voltage *Vc*

through the D/A converter D/A0.

[0049]

Subsequently, in step 111, said calculated sensor cell current *Is* is outputted as the NOx concentration current to the external device such as the ECU through the converter D/A2. Finally, in step 112, the calculated pump cell current *Ip* is outputted as the oxygen concentration current through the converter D/A3 to the external device such as ECU or a serial communication port.

[0050]

Next, a procedure for detecting the impedance will be explained according to the flowchart of Fig. 9. Like the applied voltage control, the impedance measuring operation is performed by the CPU in the control circuit 200. Fig. 9 shows an impedance measuring subroutine which is to be executed in the course of the main routine not shown. A cycle in which the impedance is detected is variably set to 128ms in a start-up mode of engine operation and 256ms after the engine is warmed up.

[0051]

In Fig. 9, first in steps 201 and 202, terminal voltages *Ve* and *Vc* of the current detecting resistor 222 are picked up through the A/D converters A/D1 and A/D0 (which will be referred to as *Ve1* and *Ve2* below). Subsequently, in step 203, the sum of a sensor cell control voltage *Vs* now applied to the sensor cell 120 and an additional a.c. voltage ΔVs is outputted from the D/A converter D/A0, thereby causing, as shown in Fig. 10, the applied voltage (the terminal voltages *Vc* and *Ve*) changes in the form of a sine wave according to the time

constant of the low-pass filter 230.

[0052]

Subsequently, in steps 204 and 205, the terminal voltages *Ve* and *Vc*, which will be referred to as *Ve2* and *Vc2* below) developed after the voltage change are picked up by the A/D converter 20 μ s after the voltage applied to the resistor 222 is changed in step 203.

[0053]

In step 206, the impedance *Zac* of the sensor cell 120 is calculated according to an equation below:

$$Zac = (Vc2 - Vc1) / \{(Ve2 - Vc2) - (Ve1 - Vc1)\}$$

Finally, in step 207, a voltage $\Delta Vs2$ is outputted from the D/A converter D/A0 temporarily to return the voltage applied to the sensor cell 120 to the voltage *Vs*.

[0054]

As described above, when the oxygen concentration and NOx concentration are measured, the voltage applied to the gas concentration sensor 100 is controlled, and a resultant current value (the pump cell current Ip and the sensor cell current Is) are detected. In this case, an electric current flowing through the gas concentration sensor 100 is extremely weak, so that it apt to interfere with electrical noises produced from peripheral devices. Particularly, when the concentration of NOx is within 0 to 2000ppm, the sensor cell current is, as shown in Fig. 6, as little as 5 to 10 μ A, thus needing a means for eliminating the noises.

[0055]

In order to reduce the effect of the noise in this embodiment, in the structure as shown in Fig. 1, the length of the signal line H1 connecting between the gas concentration sensor 100 and the sensor control circuit M10 and the length of the signal line H2 connecting between the heater 103 and the heater control circuit M20 are specified. Specifically, a relation between the length of the signal line and the sensor signal level is considered as shown in Fig. 12. The length of wire is specified according to this relation.

[0056]

Specifically, a gas concentration sensor such as the one in this embodiment designed to measure the concentration of NOx is required to shorten the length of wire extending therefrom as compared with the cup-shaped or laminated A/F sensors. Shortening the signal lines H1 and H2 eliminates the effect of noises.

[0057]

It is advisable that in a case where the gas concentration measuring apparatus is mounted in a vehicle, the distance between the gas concentration sensor 100 and the connector 300 be shortened as the sensor signal is weak.

[0058]

The element portion of the gas concentration sensor 100 is made of ceramic, so that a unit-to-unit variation of the sensor in production is great, so that the production yield is low. Specifically, a small change in production condition will result in a change in impedance or sensor output characteristic. Some of sensors not

meeting such condition need to be scrapped, thus resulting in a great decrease in production yield. The variation in characteristic, as referred to herein, a variation in output characteristic of the sensor signal in terms of the concentration of measured gas, a variation in dc current characteristic of the sensor, or a variation in ac current. For example, when the output characteristic varies, as shown in an actual output indicated by a solid line, is shifted from a correct one, as indicated by a broken line, it results in an error of detection.

[0059]

Additionally, the resistance value of the heater 103 is set small in order to speed up the activity of the gas concentration sensor 100. A variation in wire resistance between vehicles, thus, results in a variation in heater controllability, thus resulting in abnormality in controlling the heater. Specifically, resulting in a decrease in heat ability of the heater 103 and an error in measuring the power supplied to the heater, which may lead to a delay in activating the gas concentration sensor 100 and overheating thereof.

[0060]

In order to avoid the above problems in this embodiment, the detection circuits M11 to M13 have a function of adjusting or correcting the unit-to-unit variation in characteristic of the sensor, and the heater control circuit M20 has a function of adjusting or correcting an error arising from the wire resistance.

[0061]

As the adjustment/correction, there are ones capable of adjusting the gain and offset in each circuit. The adjustment is

carried out every sensor when shipped. The adjustment is achieved by

installation of adjustment parts,

installation and trimming of a thick-film resistor, or

installation of a resistor on an IC chip by ON · CHIP trimming.

[0062]

As one example, adjustment/correction circuits M31, M32, and M33, as shown in Fig. 14, are provided on output sides of the oxygen concentration determining circuit M11, the NOx concentration determining circuit M12, and the impedance measuring circuit M13, respectively. Each of the correction circuits M31 and M32 is made of a resistor as an adjustment part to adjust the output characteristic in the wider gas concentration measuring range by trimming the resistor.

[0063]

Alternatively, in a case where a microcomputer is used, gain/offset adjustment is achieved in an internal operation. Value used in this operation are stored in a memory at shipment. As a method of calculation, a typical map calculation is available. Further, values used in this calculation may be inputted from the external through the A/D converter to achieve the adjustment using the inputs.

[0064]

The above described adjustment/correction function enables an actual output to be brought into agreement with an optimum characteristic.

Similarly, to the element impedance measuring circuit M13, the adjustment/correction circuit M33 equipped with an adjustment part

(resistor) is connected. Alternatively, a correction value by the microcomputer may be inputted, thereby correcting a unit-to-unit characteristic variation in detected impedance value of the sensor.

[0065]

Similarly, to the heater control circuit M20, an adjustment/correction circuit equipped with an adjustment part (resistor) is connected. Alternatively, a correction value by the microcomputer may be inputted, thereby correcting an error arising from the wire resistance.

[0066]

The embodied form as described above offers effects as discussed below.

(a) the length of the signal lines H1 and H2 connecting the gas concentration sensor 100 electrically to the sensor control circuit M10 and the heater control circuit M20 or the distance between them is specified according to the level of a signal detected by the sensor 100. The weaker the sensor signal, the shorter the signal lines H1 and H2. In other words, the gas concentration sensor 100 is disposed in the vicinity of the control circuits M10 and M20. This structure eliminates the effect of noises even if the sensor signal is weak. As a result, the effect of noises is reduced, thereby avoiding an error of detection of the gas concentration, which achieves high accuracy gas concentration determination. Also, in this case, it is possible to specify a maximum distance between the gas concentration sensor 100 and each of the circuits M10 and M20, thus avoiding the effect of thermal disadvantage near a sensor

mount which is usually subjected to high temperature.

[0067]

(b) The oxygen concentration measuring circuit M11, the NOx concentration measuring circuit M12, the element impedance measuring circuit M13, and the heater control circuit M20 are installed integrally in the connector 300. Thus, eliminating the effect of noises, ensuring the accuracy of detecting the impedance, and improving the accuracy of output of the sensor. The integration of the respective circuits offset the advantage that it is possible to simplify the structure.

[0068]

(c) In the gas concentration sensor 100 as the so0-called composite gas sensor equipped with the pump cell 110 for detecting the concentration of oxygen in exhaust gasses and the sensor cell 120 for detecting the concentration of NOx, the sensor cell current will be weak, thus resulting in difficulty in determining the concentration of NOx accurately in the presence of noises, but however, the above described structure eliminates this problem and offers the considerable effect.

[0069]

(d) The sensor control circuit M10 has the adjustment/correction function of correcting a characteristic unit-to-unit variation of the sensor. The heater control circuit M20 has the adjustment/correction function of correcting an error arising from the wire resistance of the heater 103. This eliminate a unit-to-unit difference of the gas concentration sensor 100, thus enabling an

actual output of the sensor to be brought into agreement with an optimum characteristic. This also results in stability of the heater control, thus alleviating problems related to a delay in activating the element and overheating of the element. As a result, the production yield of the gas concentration sensor and the gas concentration apparatus is greatly improved. In this case, complex adjustment needs not be required for every sensor through the ECU 20, thus eliminating a load on the ECU 20. It is possible to have the adjustment/correction function in a relatively easy manner.

[0070]

The embodiment of the invention may be embodied in the following forms.

In the above described embodied form, the oxygen concentration measuring circuit M11, the NOx concentration measuring circuit M12, the element impedance measuring circuit M13, and the heater control circuit M20 are built in the connector 300, and the length of the signal lines H1 and H2 connecting the gas concentration sensor 100 to the connector 300 and the distance between them are specified, but this structure is altered. Only the NOx concentration measuring circuit M12 picking in the weak sensor cell to determine the concentration of NOx is built in the connector 300, and the length of a signal line from the sensor 100 is specified. Specifically, the length of the signal line between the gas concentration sensor 100 and the NOx concentration measuring circuit M12 or the distance therebetween is shortened in a range where the effect of noises is low.

[0071]

Additionally, any one of the oxygen concentration determining circuit M11, the element impedance measuring circuit M13, and the heater control circuit M20 may also be disposed within the connector 300 in addition to the NOx concentration measuring circuit M12. Of course, it is advisable that each circuit M11 to M13, and M20 be located as near the gas concentration sensor 100 as possible. Selection of the length of the signal line increases the freedom of design. In this case, it is possible to specify a maximum distance between the gas concentration sensor 100 and each circuit M11 to M13, and M20, thus avoiding the effect of thermal disadvantage near a sensor mount which is subjected to higher temperatures.

[0072]

In the above embodiment, the first sensor cell electrode 121 and the second pump cell electrode 112 are, as clearly shown in Fig. 7, connected to ground, but may alternatively be connected to a common terminal which is kept at a positive potential. This allows a negative electric current to flow through each of the pump cell 110 and the sensor cell 120. Thus, even when a rich gas which usually reduces a flow of the negative current and changes a balance of concentration of O_2 in the porous diffused layer 101 enters the gas concentration sensor 100, it becomes possible to keep the concentration of gas, for example, O_2 in the porous diffused layer 101 at a constant value equivalent to the stoichiometric. This enables the rich gas to be measured accurately, thus resulting in an increase in measurable range of the gas concentration sensor 100 and also results in greatly improved

response rate of the gas concentration sensor 100 when the gas returns from the rich to lean side.

[0073]

The present invention may be used with an air-fuel ratio (A/F) sensor designed to measure the concentration of O_2 contained in exhaust gasses for determining an air-fuel ratio (A/F value). In this case, the invention may be used with a so called cup-shaped A/F sensor in which a solid electrolyte body and a diffused resistance layer are cup-shaped and a laminated A/F sensor made of a lamination of a solid electrolyte plate and a diffused resistance layer. When the air-fuel ratio is 12 to 18, the laminated A/F sensor outputs a current signal of as little as –0.75 to 0.4mA, but the structure of this invention reduces addition of electric noises to an output of the laminated A/F sensor sufficiently and avoids an error in measurement of the gas concentration. When the current output is between –0.75 to 0.4mmA at A/F = 12 to 18, the current value per 1A/F will be approximately 0,2mA. A required accuracy for detection of the air fuel ratio will be less than 10% of 0.2mA, namely, less than 20 μA.

[0074]

The present invention may also be used with three-cell or four-cell gas concentration sensors in addition to the two-cell structure as illustrated in Fig. 2.

[0075]

The present invention may further be used with a gas concentration sensor as a composite sensor which is designed to decompose and discharge O_2 contained in gasses to be measured

through a pump cell and decompose HC and/or CO contained in the gasses after the decomposition of O_2 through a sensor cell for determining the concentration of O_2 and the concentration of HC and/or CO. Of course, the invention may also be used with a gas concentration sensor which is designed to only one of the NOx, HC, and CO concentrations.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 is a structural view which shows the summary of an engine control system in an embodied form of the invention;

Fig. 2 is a block diagram which shows substantially a structure of a gas concentration measuring apparatus;

Fig. 3 is an essential part sectional view which shows a structure of a gas concentration sensor;

Fig. 4 is an illustration for explaining operational principle of a gas concentration sensor;

Fig. 5 is a V-I characteristic view for explaining a pump cell characteristic of a gas concentration sensor;

Fig. 6 is a V-I characteristic view for explaining a sensor cell characteristic of a gas concentration sensor;

Fig. 7 is a circuit diagram which shows an electrical structure of a gas concentration measuring apparatus;

Fig. 8 is a flowchart which shows a procedure for controlling applied voltage;

Fig. 9 is a flowchart which shows a procedure for measuring impedance;

Fig. 10 is a waveform view which shows a change in a signal

when impedance is measured;

Fig. 11 is a perspective view which shows the externals of a gas concentration sensor and a connector;

Fig. 12 is an illustration which shows a relation between the length of wire and the level of a sensor signal;

Fig. 13 is an illustration which shows a relation between a sensor output and an oxygen concentration; and

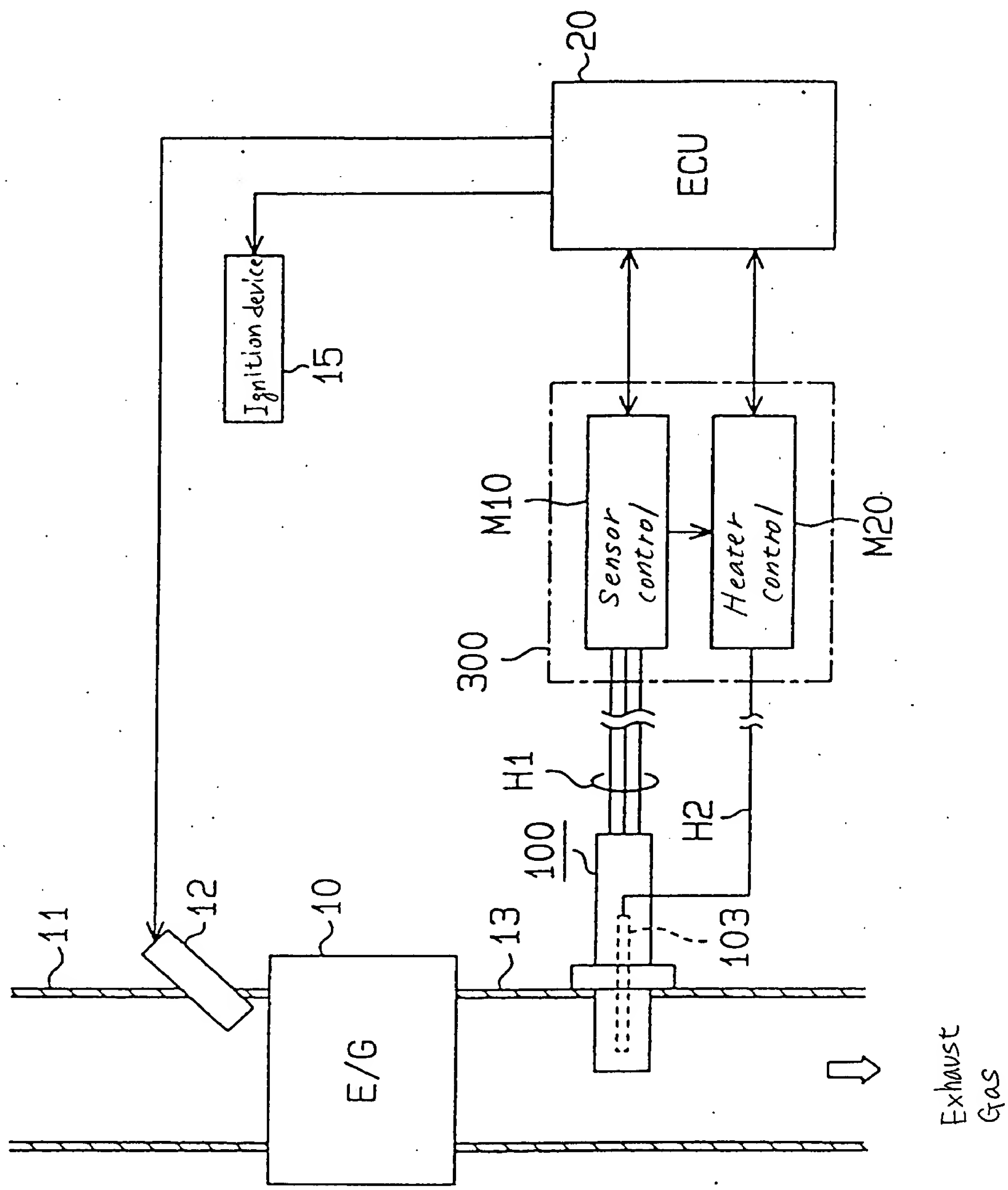
Fig. 14 is a block diagram which substantially shows a structure of a gas concentration measuring apparatus.

[EXPLANATION OF REFERENCE NUMBERS]

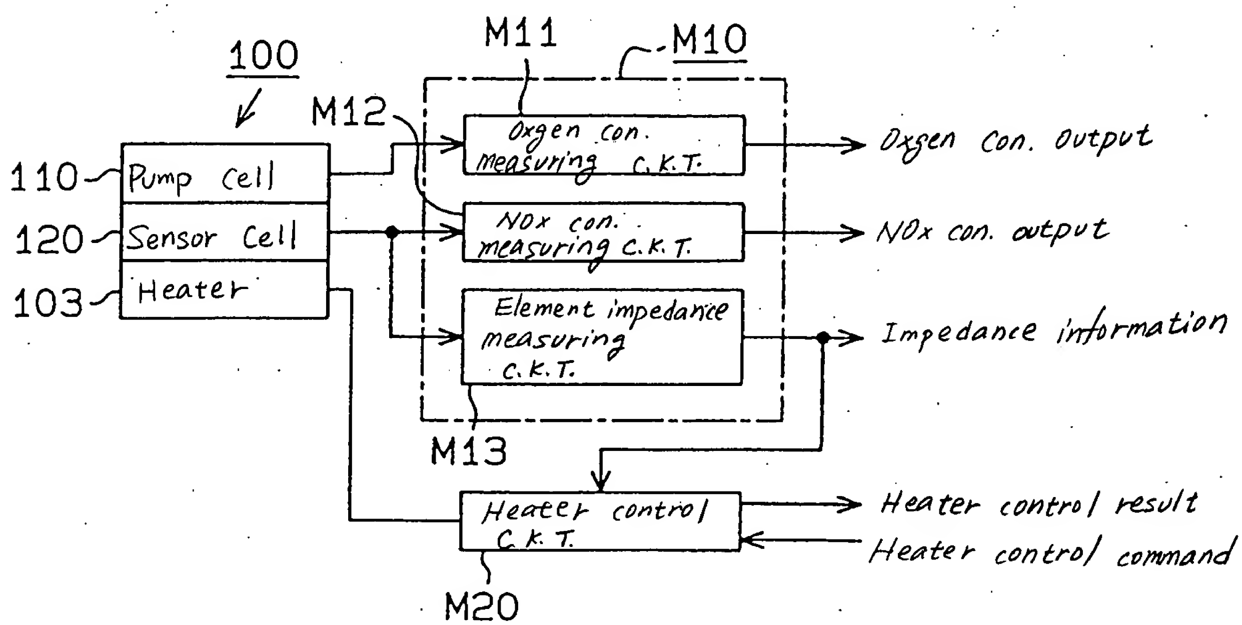
100 – gas concentration sensor, 110 – a pump cell as a first cell, 120 – sensor cell as a second cell, 103 – heater, 150 – element portion, 200 – control circuit, 300 – connector, M10 – sensor control circuit, M11 – oxygen concentration measuring circuit as a signal processing circuit, M12 – NOx concentration measuring circuit as a signal processing circuit, M13 – element impedance measuring circuit, M20 – heater control circuit, M31, M32, and M33 – adjustment/correction circuits, H1 and H2 – signal line.

【書類名】　　　図面

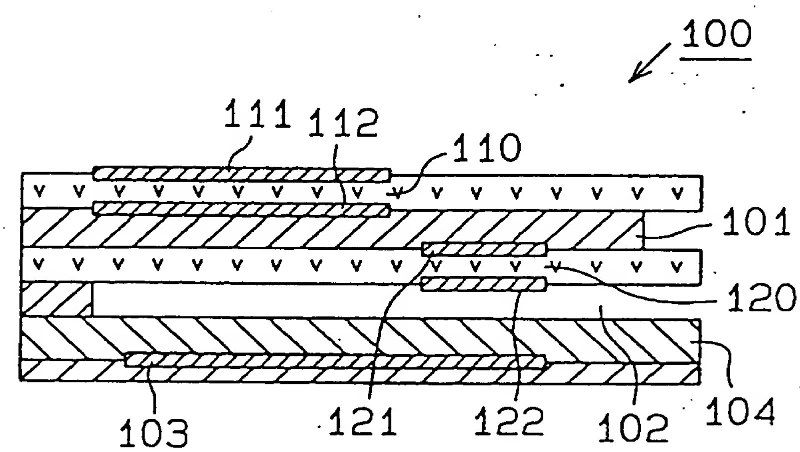
【図１】 Fig. 1



【図２】 Fig. 2

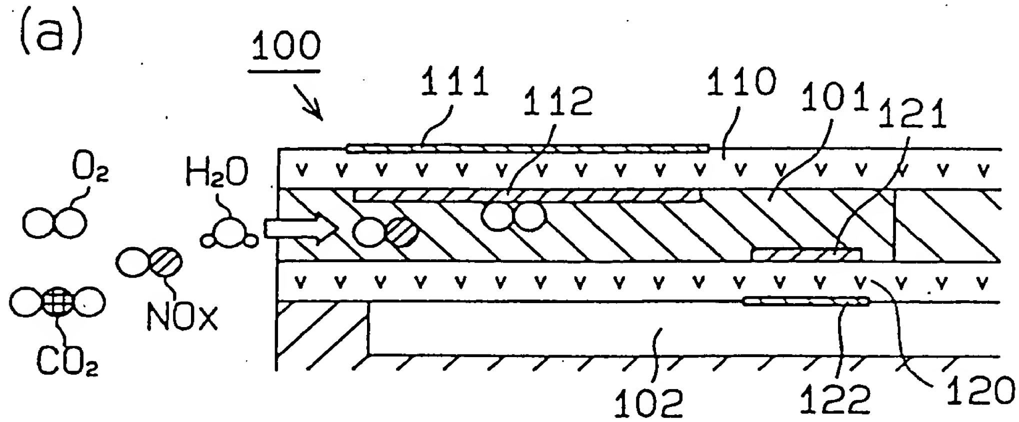


【図３】 Fig. 3

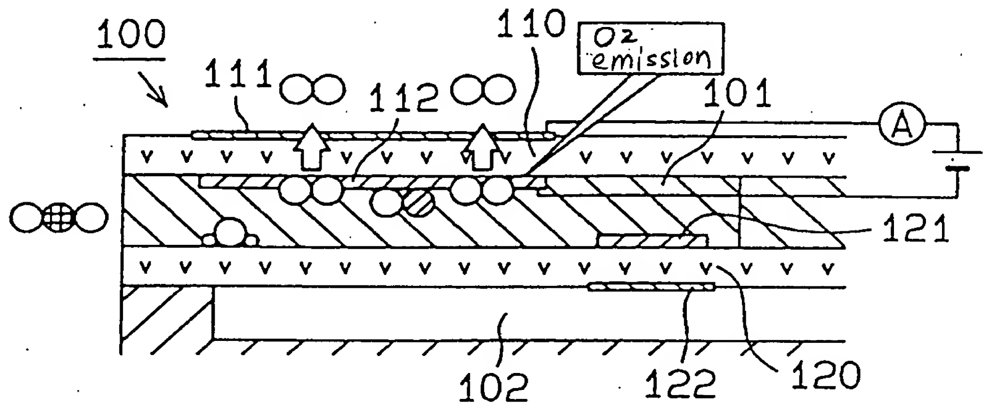


【図４】 Fig. 4

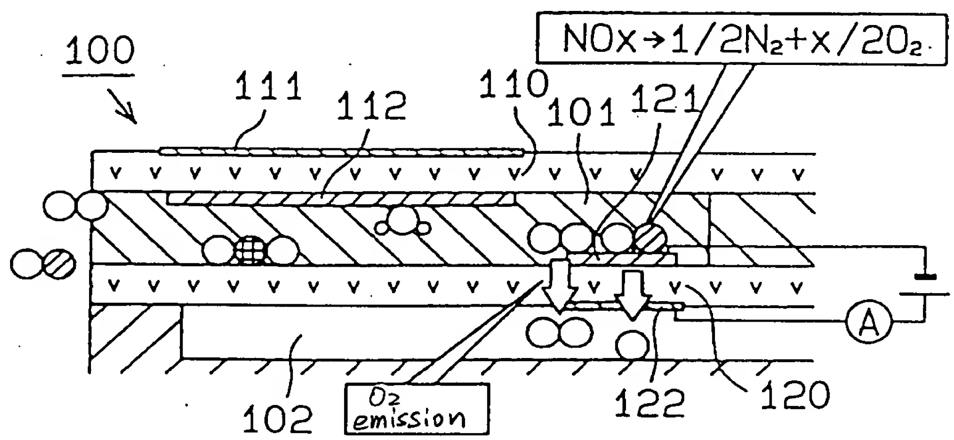
(a)


100
111
112
110
101
121
O_2
H_2O
NOx
CO_2
102
122
120

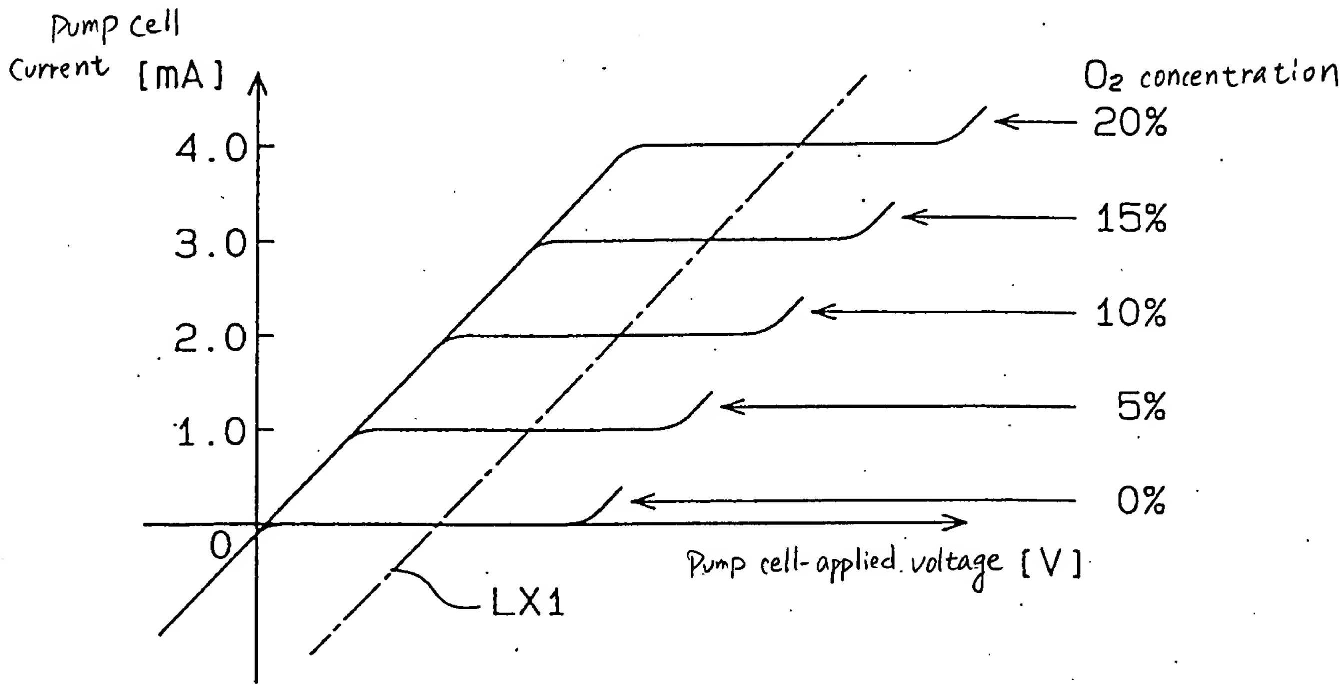
(b)


100
111
112
110
O_2 emission
101
A
121
102
122
120

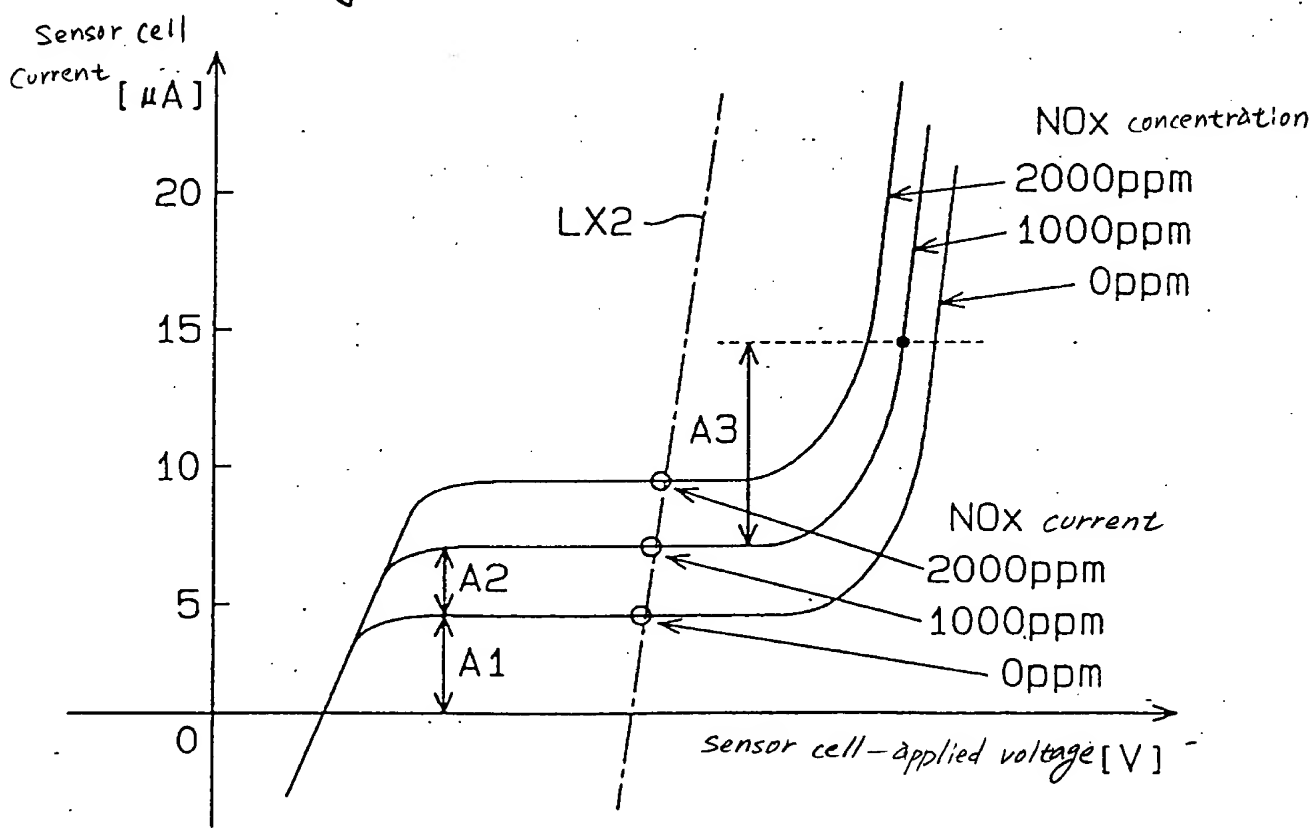
(c)


NOx→1/2N2+x/2O2
100
111
112
110
101
121
A
102
O_2 emission
122
120

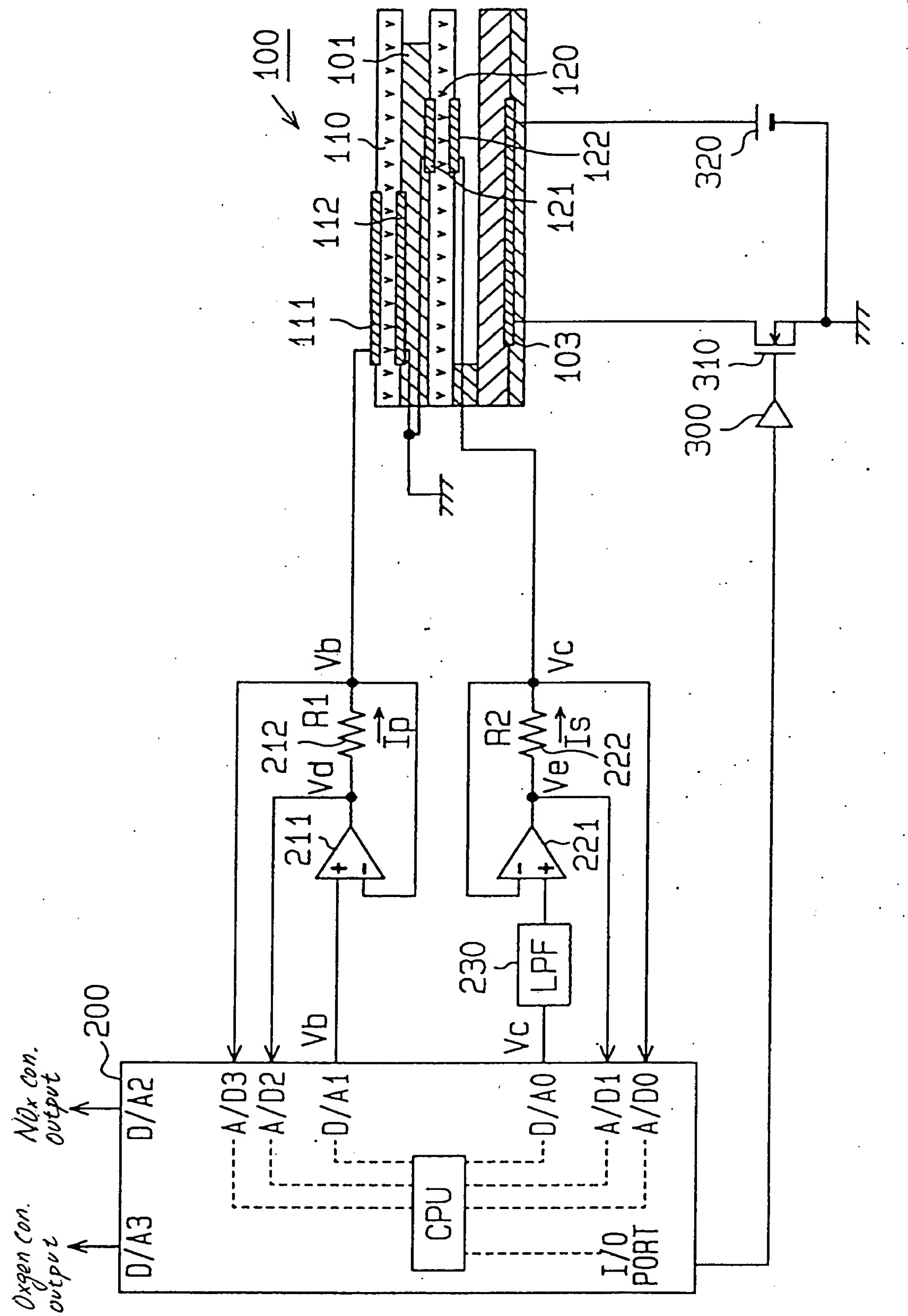
【図５】　Fig. 5



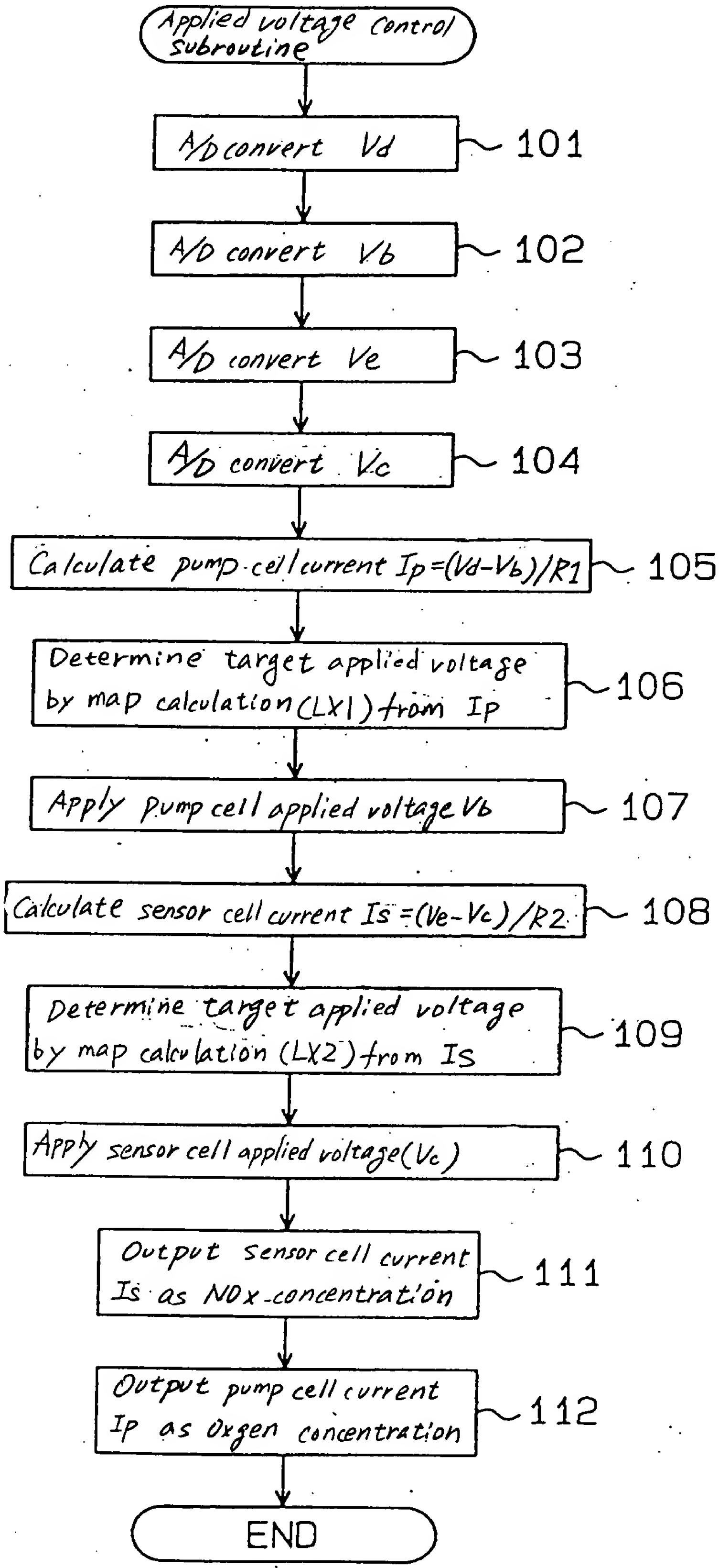
【図６】　Fig. 6



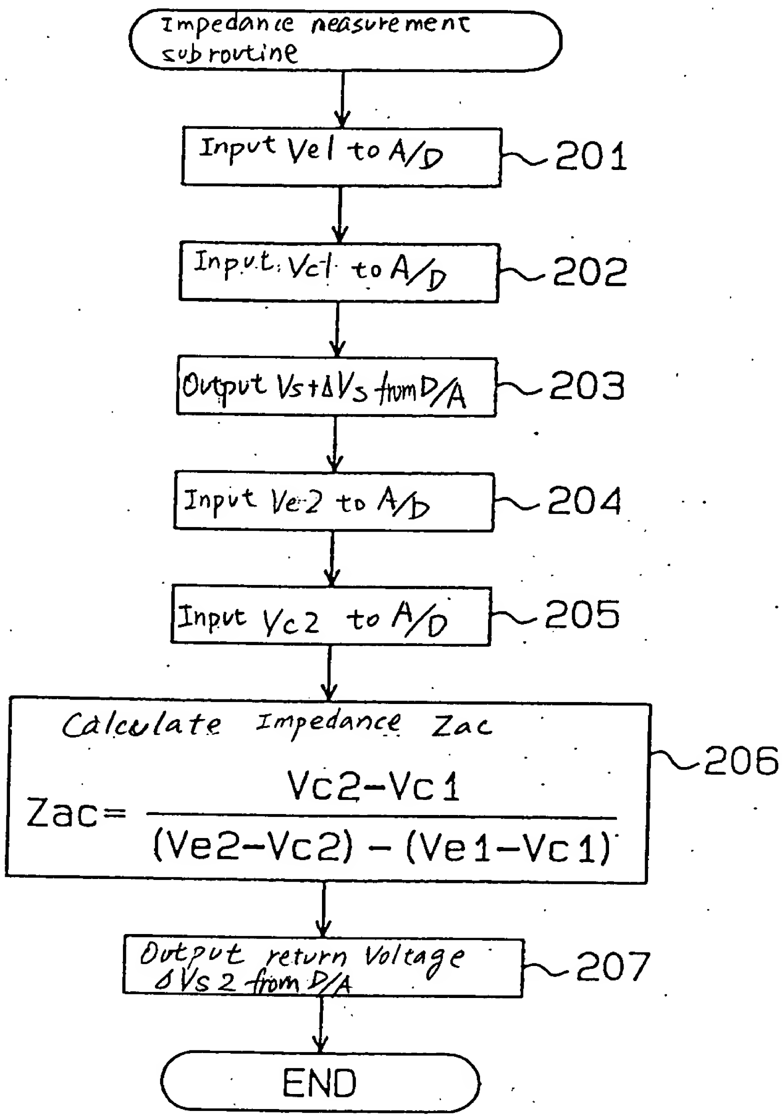
【図７】 Fig. 7


100
101
110
112
111
120
122
121
103
320
310
300
Vb
Vc
212
R1
Ip
Vd
211
R2
Is
Ve
222
221
230
LPF
200
D/A2
D/A3
A/D3
A/D2
D/A1
D/A0
A/D1
A/D0
CPU
I/O PORT
NOx con. output
Oxgen con. output

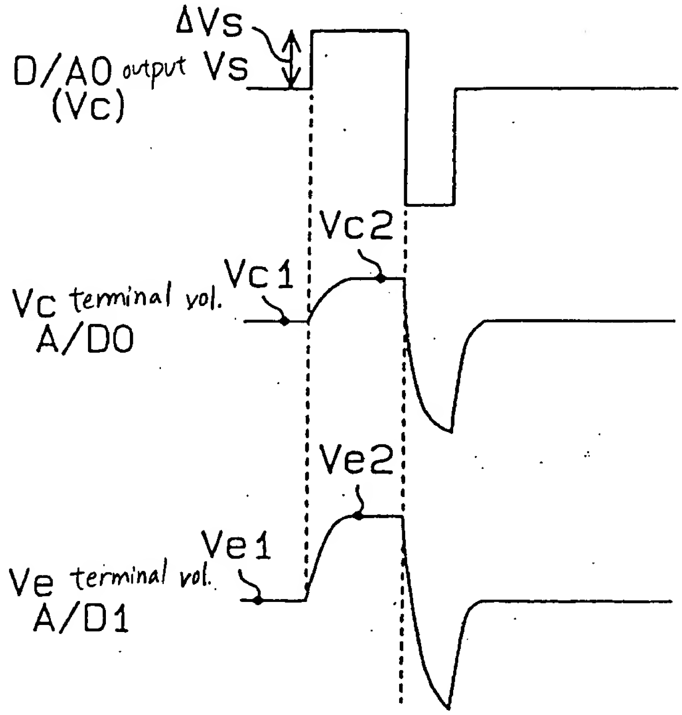
【図８】　Fig. 8


Applied voltage control subroutine
A/D convert Vd
101
A/D convert Vb
102
A/D convert Ve
103
A/D convert Vc
104
Calculate pump cell current Ip=(Vd-Vb)/R1
105
Determine target applied voltage by map calculation (LX1) from Ip
106
Apply pump cell applied voltage Vb
107
Calculate sensor cell current Is=(Ve-Vc)/R2
108
Determine target applied voltage by map calculation (LX2) from Is
109
Apply sensor cell applied voltage (Vc)
110
Output sensor cell current Is as NOx concentration
111
Output pump cell current Ip as Oxgen concentration
112
END

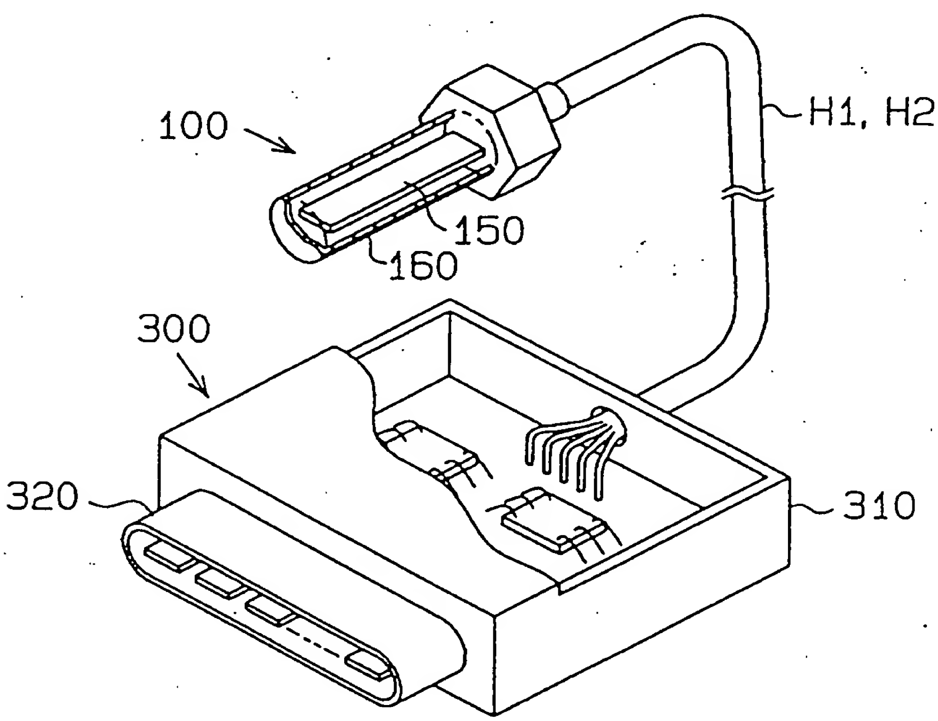
【図９】 Fig. 9


Impedance neasurement subroutine
Input Ve1 to A/D
201
Input Vc1 to A/D
202
Output Vs+ΔVs from D/A
203
Input Ve2 to A/D
204
Input Vc2 to A/D
205
Calculate Impedance Zac
Zac= (Vc2−Vc1) / ((Ve2−Vc2)−(Ve1−Vc1))
206
Output return Voltage δVs2 from D/A
207
END

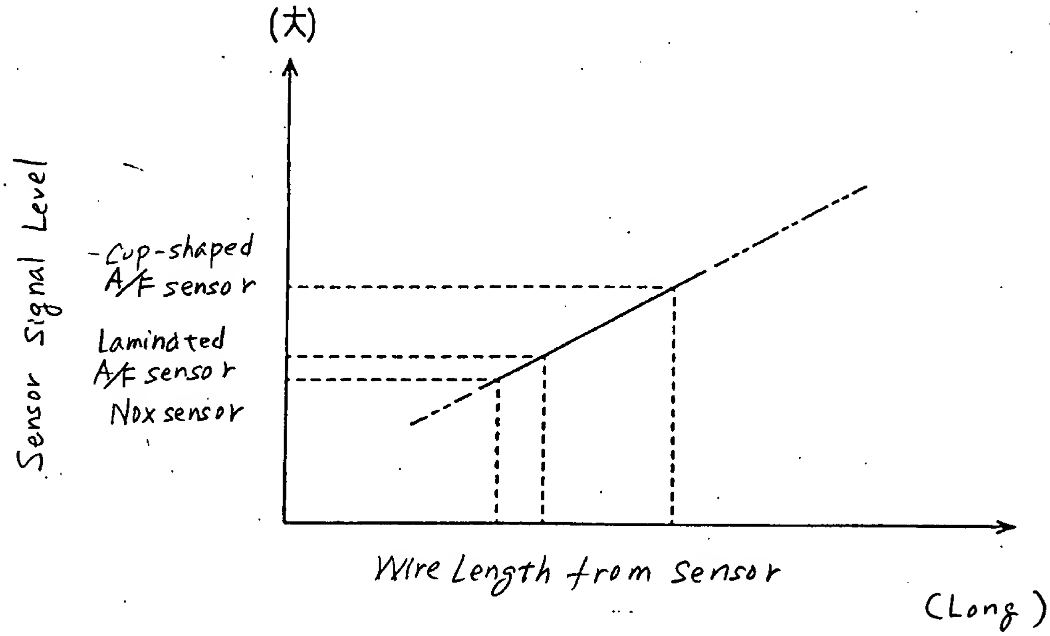
【図１０】 Fig.10



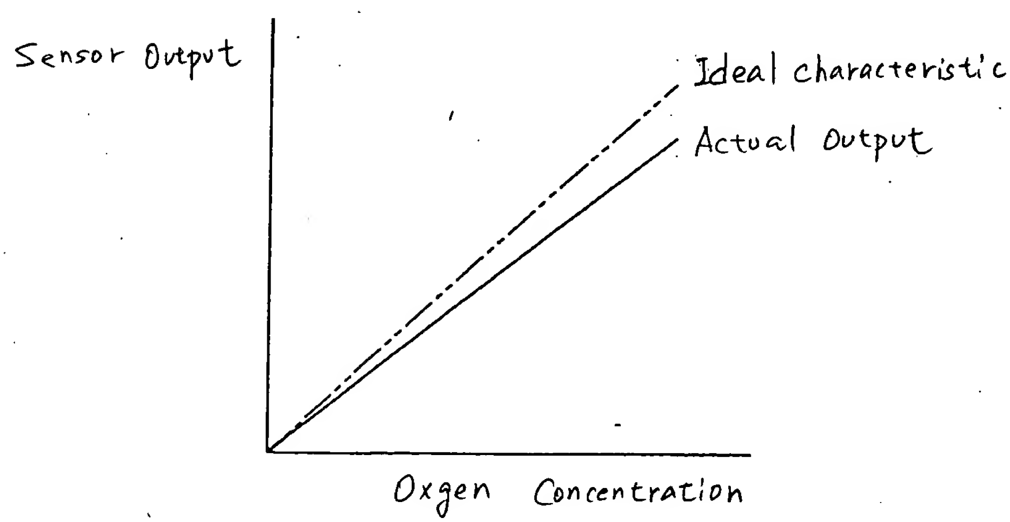
【図１１】 Fig.11



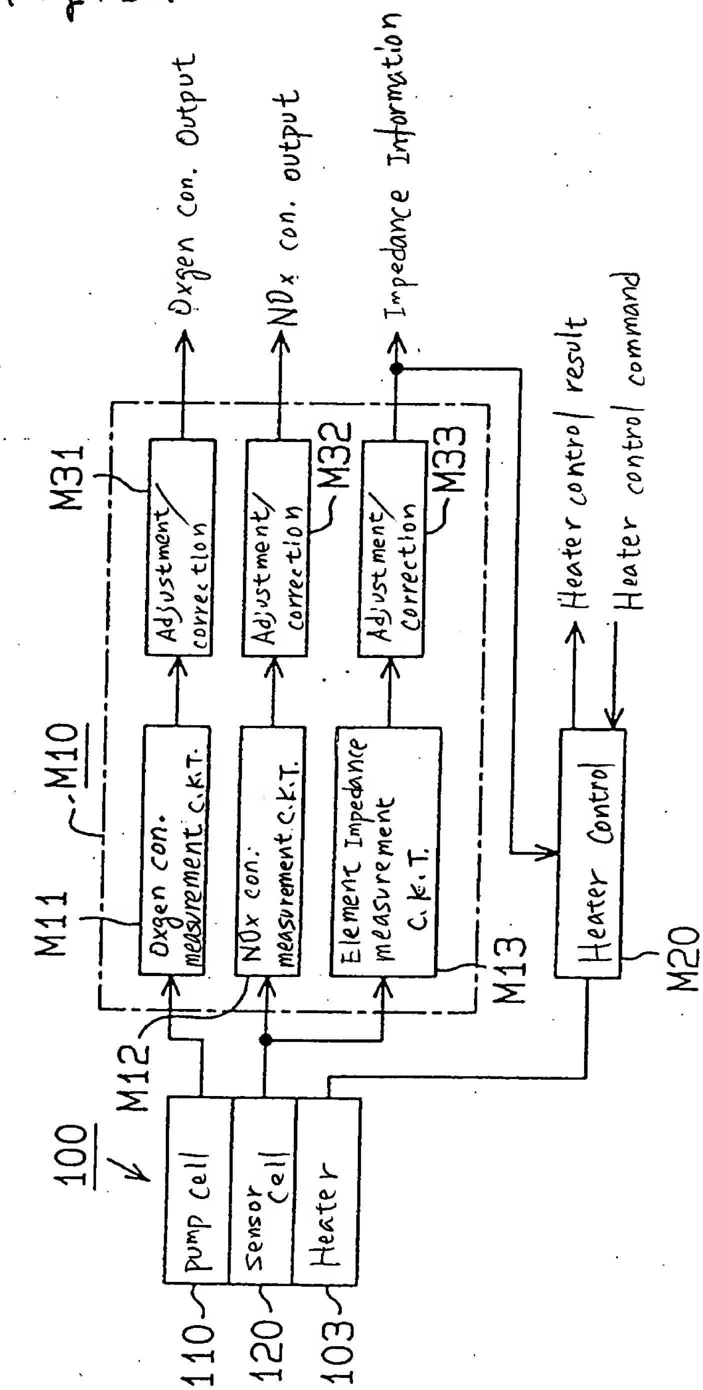
【図１２】　Fig. 12



【図１３】　Fig. 13



【図１４】 Fig.14


Oxgen con. Output
NOx con. output
Impedance Information
M31
M32
M33
Adjustment/correction
Adjustment/correction
Adjustment/correction
M10
M11
M12
M13
Oxgen con. measurement c.k.T.
NOx con. measurement c.k.T.
Element Impedance measurement c.k.T.
Heater control/ result
Heater control command
Heater Control
M20
100
Pump cell
Sensor Cell
Heater
110
120
103

[NAME OF DOCUMENT] SUMMARIZED DOCUMENT

[SUMMARY]

[PROBLEM] To eliminate effect of noise, thus avoiding an error in measuring a gas concentration.

[SOLVING MEANS] A detected signal of the gas concentration sensor 100 is inputted to the sensor control circuit M10. The control circuit M10 calculates an oxygen concentration output and a NOx concentration output from the sensor detected signal and also measures an element impedance of the gas concentration sensor 100. The sensor control circuit M10 and the heater control circuit M20 are both built in the connector 300. the gas concentration sensor 100 is electrically connected to the sensor control circuit M10 in the connector 300 through the signal line H1. The heater 103 is electrically connected to the heater control circuit M20 in the connector 300 through the signal line H2. The length of the signal lines H1 and H2 from the gas concentration sensor 100 is specified as a function of a level of the detected signal by the sensor 100. The weaker the sensor signal, the shorter the signal lines H1 and H2.

[SELECTED DRAWING] Fig. 1

APPLICANT'S PERSONAL HISTORY INFORMATION

Identification Number [000004260]

1. Date of Change October 8, 1996

   [Reason for Change] For change of Designation

   Address: 1-1, Showa-cho, Kariya-shi, Aichi-ken

   Name: Denso Corporation

APPLICANT'S PERSONAL HISTORY INFORMATION

Identification Number [000004695]

1. Date of Change August 7, 1990

[Reason for Change] For change of Designation

Address: 14, Iwaya, Shimohasumi-cho, Nishio-city
Aichi-ken

Name: Nippon Soken, Inc.